1 Positive current prioritization

Given a generic disposition of positive and negative voltages as shown in Fig. 1, we are concerned with determining the maximum negative sequence current capacity.

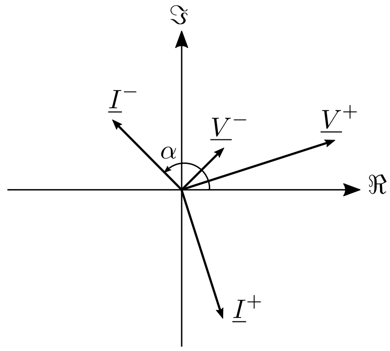

Figure 1: General representation of positive and negative sequence currents and voltages

Currents are delayed or advanced $\frac{\pi}{2}$ in order to only inject reactive power. As limitations are imposed in the phases (natural reference frame), currents are transformed as follows

$$\begin{pmatrix} \underline{I}_a \\ \underline{I}_b \\ \underline{I}_c \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ 1 & \underline{a}^2 & \underline{a} \\ 1 & \underline{a} & \underline{a}^2 \end{pmatrix} \begin{pmatrix} 0 \\ \underline{I}^+ \\ \underline{I}^- \end{pmatrix} \tag{1}$$

where $\underline{a} = e^{j\frac{2\pi}{3}}$ and the zero sequence current is forced to be null. Then, phase currents are expressed as

$$\begin{cases} \underline{I}_a = \underline{I}^+ + \underline{I}^- \\ \underline{I}_b = \underline{a}^2\underline{I}^+ + \underline{a}\underline{I}^- \\ \underline{I}_c = \underline{a}\underline{I}^+ + \underline{a}^2\underline{I}^- \end{cases} \tag{2}$$

It is now convenient to write the previous expressions without the operator a explicitly shown:

$$\begin{cases} \underline{I}_a = \underline{I}_a^+ + \underline{I}_a^- \\ \underline{I}_b = \underline{I}_b^+ + \underline{I}_b^- \\ \underline{I}_c = \underline{I}_c^+ + \underline{I}_c^- \end{cases} \tag{3}$$

where $\underline{I}_c^+ = \underline{a}\underline{I}^+$ and $\underline{I}_c^- = \underline{a}^2\underline{I}^-$, and analogously for other phases. All three cases have to be computed, yet the smallest negative sequence current (i.e., $\texttt{min}(I_a^-, I_b^-, I_c^-)$) acts as the most restrictive option.

Next, all phase currents are set to its maximum value, denoted by $I_{\max}$. Thus, squaring them:

$$\begin{cases} I_{\max}^2 = (I_{a,re}^+ + I_{a,re}^-)^2 + (I_{a,im}^+ + t_a I_{a,re}^-)^2 \\ I_{\max}^2 = (I_{b,re}^+ + I_{b,re}^-)^2 + (I_{b,im}^+ + t_b I_{b,re}^-)^2 \\ I_{\max}^2 = (I_{c,re}^+ + I_{c,re}^-)^2 + (I_{c,im}^+ + t_c I_{c,re}^-)^2 \end{cases} \tag{4}$$

which has to be solved for $I_{a,re}^-, I_{b,re}^-$ and $I_{c,re}^-$, where t_a, t_b and t_c represent the proportion between the imaginary and the real part of the particular negative sequence components. In other words, if phasor $\underline{I}^-$ is at an angle α, as indicated in Fig. 1, then:

$$\begin{cases} t_a \equiv \tan(\alpha) = \frac{I_{a,im}^-}{I_{a,re}^-} \\ t_b \equiv \tan(\alpha + \frac{2\pi}{3}) = \frac{I_{b,im}^-}{I_{b,re}^-} \\ t_c \equiv \tan(\alpha - \frac{2\pi}{3}) = \frac{I_{c,im}^-}{I_{c,re}^-} \end{cases} \tag{5}$$

The final step is to solve each one of the three quadratic equations that are derived from (4), select the appropriate solution according to the already known direction, and compute the absolute value of these negative sequence currents

$$\begin{cases} I_a^- = \sqrt{(I_{a,re}^-)^2 + (t_a I_{a,re}^-)^2} \\ I_b^- = \sqrt{(I_{b,re}^-)^2 + (t_b I_{b,re}^-)^2} \\ I_c^- = \sqrt{(I_{c,re}^-)^2 + (t_c I_{c,re}^-)^2} \end{cases} \tag{6}$$

2 Negative current prioritization